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IDENTIFICATION OF FLOAT GLASS SURFACES

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Methods for identifying the lower (contacting with tin melt) and the upper (contacting with gaseous atmosphere) surfaces of float glass are considered.

The fact that the chemical composition of surface layer of float glass due to its tin concentration differs significantly from the glass volume composition is well known. Numerous publications describe chemical characteristics of float glass surfaces investigated using electron microscopy,

X-ray-fluorescence analysis, ellipsometry, secondary ion mass spectrometry, and ESCA [1 – 3]. All these methods make it possible to reliably identify the surfaces of float glass and investigate their properties, but they are too complicated for practical use and require expensive equipment.

It has been established using the above methods that a sharp increase in the concentration of tin occurs only within the surface layer approximately 10 nm depth, after which its content with depth sharply drops and then varies insignificantly. The increased tin concentration is observed both on the surface contacting the tank (the bottom surface) and on the surface contacting air (the upper surface). However, the weight content of tin in the upper surface layer is around 0.1%, whereas on the bottom surface it may reach approximately 2%, i.e., the float glass surfaces differ significantly in their composition, which determines their different properties. These differences cannot be detected visually, although in practical application it is often necessary to identify the upper and lower surfaces. For instance, when coatings are deposited on a glass sheet, it is recommended to deposit them on the surface that does not contact tin.

The present paper lists some physical properties of float glass surfaces whose dependence on chemical composition is clear enough and can serve as an instrument for identifying the top and the bottom of a glass sheet. We have selected methods that can be easily enough implemented in practice without expensive equipment.

It should be primarily noted that tin concentration leads to structural modifications in glass, i.e., it changes the number of bridge Si – O – Si bonds and nonbridge $Si – O^-$ bonds (the number of the former decreases and that of the latter grows). Since the content of tin on the top and bottom surfaces differs by at least an order of magnitude (they can be arbitrarily denoted as surfaces “with tin” and “without tin”, respectively), their degree of structural modification differs as well. This is clearly seen in infrared reflection spectra depending on the ratio between the intensities of stretching vibration of bridge bonds $\nu_{Si – O – Si}$ and nonbridge bonds $\nu_{Si – O^-}$ and on the position of the main maximum. In the reflection spectra registered with the IR spectrophotometer in the range of 1200 – 700 cm^{-1}, the main maximum of $\nu_{Si – O – Si}$ on the bottom surface is shifted by about 5 – 10 cm^{-1} toward longer waves compared to its position in the upper surface spectrum (from 1060 to 1050 cm^{-1}), whereas the intensity in the range of 950 cm^{-1} ($\nu_{Si – O^-}$) grows. This is clearly seen in the superposition of the spectra (Fig. 1).

A difference in the values of the refractive index n is registered for the top and bottom surfaces. When measured using an IRF refractometer (or a similar instrument) in daylight or electric light, (i.e., nonmonochromatic radiation), the difference between the refractive indexes is equal to about 3 units in the third decimal place: in the contact of the measuring porism with the bottom surface (with tin) the refractive index is 1.518 – 1.519, whereas in the contact with the surface without tin it is equal to 1.515 – 1.516.

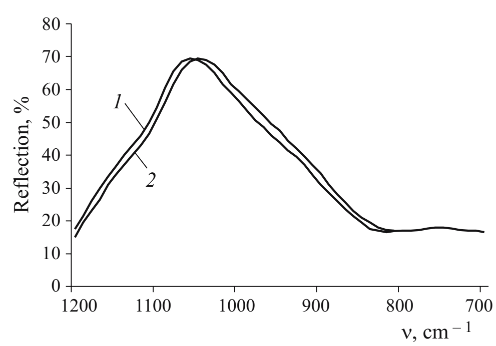

Fig. 1. IR reflection spectra of float glass: upper surface without tin (*1*) and bottom surface with tin (*2*).

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TABLE 1

Arbitrary number of company	Parameters of IR reflection spectra: $\nu_{max} = \nu_{Si-O-Si}$, cm^{-1} for surface		$I_{950}/I_{max} = I_{Si-O^-}/I_{Si-O-Si}$ for surface		Refractive index on surface		Contact wetting angle of surface, deg	
	without tin	with tin	without tin	with tin	without tin	with tin	without tin	with tin
1	1060 – 1063	1050	0.66 – 0.67	0.69 – 0.71	1.515	1.5183	22	52
							18	48
							26	50
							23	48
2	1060	1050	0.66 – 0.68	0.69 – 0.70	1.516	1.5188	22	41
3	1065	1055	0.63 – 0.66	0.67 – 0.70	1.515	1.5181	21	61
							20	63
4	–	–	–	–	1.515	1.5180	26	62
5	1065	1050	0.65	0.68	1.515	1.5185	21	59
6	1060	1050	0.63	0.68	1.515	1.5185	21	62
7	1063	1050	0.65	0.66 – 0.69	1.516	1.5183	20	42
8	–	–	–	–	1.515	1.5188	23	63
							22	60

The difference in the refractive index for different surfaces indicates a difference in their light reflection coefficients, although insignificant. Under normal incidence, when the reflection coefficient

$$\rho = (1 - n)^2/(1 + n)^2,$$

it is not more than five hundredth of a percent. Considering that the difference is so insignificant, it is hard to register in standard measurements of the reflection coefficient. However, this can be achieved by tuning the instrument to enhanced sensitivity, for instance, the instrument POS-1 used at glass factories to measure the light reflection coefficient in accordance with GOST 26302–93 can be tuned so that the indicator (microampermeter) pointer reflected from both surfaces of the sample be at the level of approximately 90 units (for 100-unit scale), and then reflection from the surface with tin is approximately 50 units and reflection from the surface without tin is about 45 units. If we need the reflection indicator to show only one surface, the second (opposite) surface should be dulled, for instance, using emery paper.

Surfaces with different tin content have significantly different wettability. Thus, the contact wetting angle of the surface with tin for distilled water at room temperature exceeds by about 20° or more the wetting angle of the surface without tin. The degree of discrepancy between the wetting angles can vary in glasses made by different producers (or glasses produced by the same producer at different times) and may reach 40 – 45°. This makes it possible to easily and quickly distinguish between the surfaces. The difference between the wetting angles makes it possible to indirectly asses tin entrainment from the melt, which can be useful for technologists: the higher the difference, the larger the entrainment.

In some cases the entrainment of tin can be so significant that its oxides form a film on the bottom surface of glass; in that case the surfaces can be easily differentiated by measuring resistivity which sharply decreases on the bottom surface (approximately from 10^7 to $10^3\ \Omega \cdot cm$) or by observing the fluorescence of the oxide film in ultraviolet light.

The above list of typical differences in the physical properties of float glass surfaces is not exhausting, however, it can be convenient for identifying the upper (without tin) and lower (with tin) surfaces without resorting to expensive and complicated methods. It should be noted that the specified differences in the physical properties of surfaces are common for all float glasses (produced by all considered companies). A distinction may consist in the degree of these differences, for instance, in the case of a difference between the contact wetting angles. It should be noted that the tin content in the surface layer of glass varies significantly from one factory to another and also for a particular factory at different production periods, since this parameter perceptibly depends on the conditions of the glass ribbon formation, in particular on temperature distribution in the melt tank, the composition of the protective atmosphere, and the quantity and chemical composition of cullet used (including, the content of tin in the cullet).

By way of illustration Table 1 lists statistical data on glasses produced by various companies.

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